CHAPTER 3

VERTICAL CONTROL - BENCH MARKS

3-1. Selection of Monument Type Based on Local Site Conditions. Types of marks to be used for vertical control are a function of the order of accuracy of the survey, the intended use of the data collected, and the site conditions. The types of monuments that can be used for vertical control, depending on local site conditions, are identified in Table 3-1. Construction and installation details are discussed in the following paragraphs.

Table 3-1

Site Conditions and Monument Types for Vertical Control

Site Conditions	Order of Accuracy			
	High	1	2	3
Rock outcrops, large boulders, bedrock concrete structures (more than 5 years old)	C	C	C	C
Granular soils (sand and gravel)	B	A,B	A	F,G
Glaciated soils (till)	B	A,B	A	F,G
Fine-grained soils (silts and clays with high bearing strengths)	B	A,B	A	F,G
Fine-grained soils (silts and clays with low bearing strengths)	B	A,B	A	A
Construction fill (disturbed earth)	B	A,B	A	A
Permafrost	E	E	D,E	D
Marsh	B	B	B	A
Subsidence area	B	B	B	A

a. Type A - Deep Rod - Aluminum with Finned Section. Type A rod marks (Figure 3-1) should be used when sound bedrock or substantially stable structures are not available. The mark is provided with extra horizontal stability required for three-dimensional surveys, which makes the mark a suitable GPS mark. This mark should not be used in highly corrosive environments.

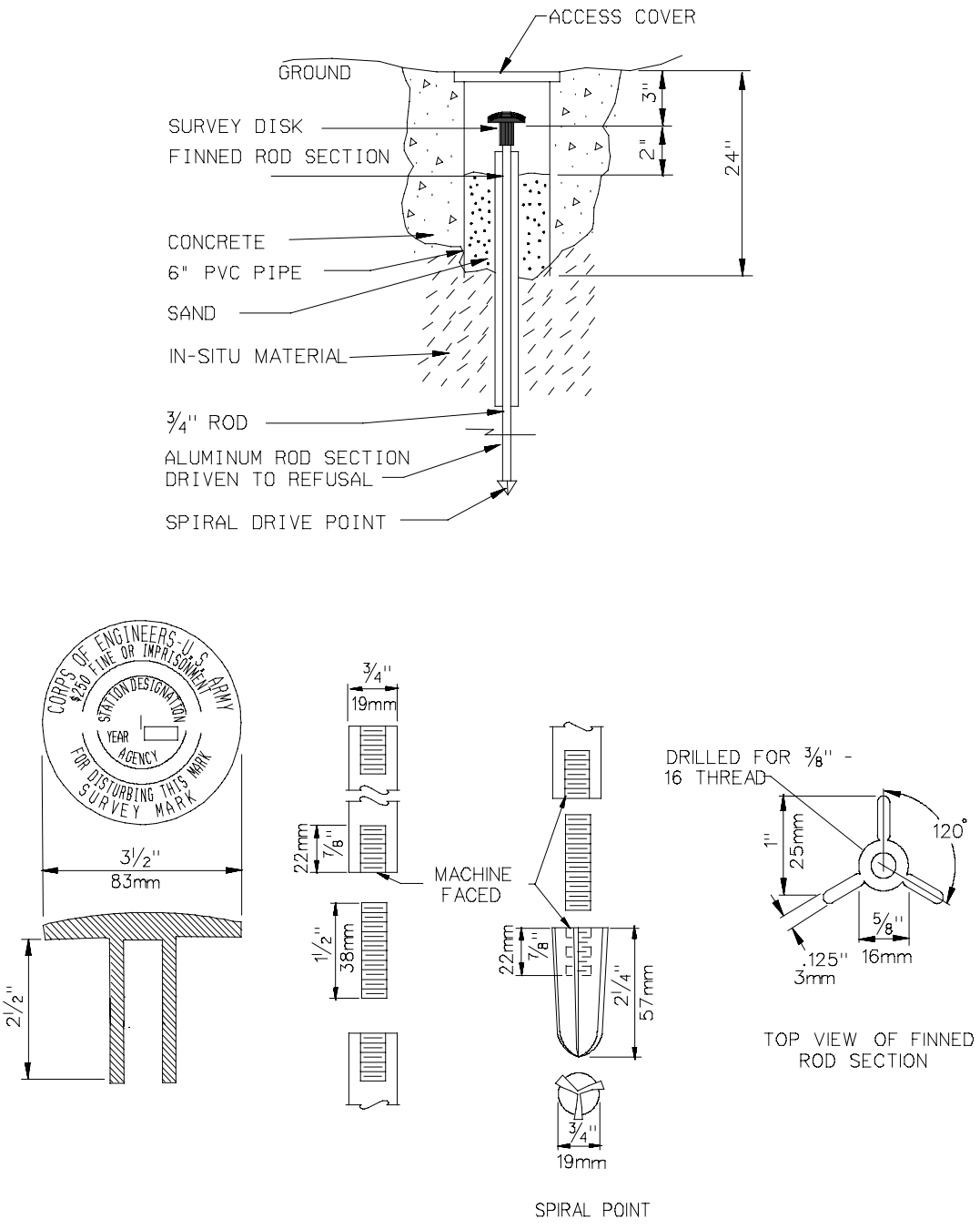


Figure 3-1. Type A monument - deep rod - 3-foot finned section

Table 3-1 indicates the recommended usage for the Type A monument.

b. Type B - Deep Rod - Stainless Steel with Sleeve. Type B rod marks (Figure 3-2) should also be used when sound bedrock or substantially stable structures are not available. Type B rod marks shall always be used in highly corrosive environments. Since this mark is also provided with horizontal stability, it may also be used as a three-dimensional monument.

c. Type C - Disk in Bedrock or Concrete Structures. Sound bedrock is the most desirable location for a bench mark as illustrated by Type C monument (Figure 3-3); it provides the most stable setting in terms of both underground activity and potential disturbances. Always use bedrock when a suitable outcrop exists. As a rule of thumb, a bedrock outcrop is considered acceptable if the distance between adjacent joints and fissures is greater than 1 meter (40 inches).

d. Type D - Deep Rod - Frost Resistant (Anchored in Permafrost). Changes in bench mark position caused by frost heave can occur where soil freezes and thaws annually. This problem is most severe where annual frost penetrates deeply. Figure 3-4 illustrates the maximum depth of frost in meters for the United States. Significant subsurface movement of soil in permafrost areas can occur to depths of up to 9 meters (30 feet), and conventional bench marks can be moved several inches due to frost heave in winter and subsequent settlement during summer thaws. Type D monuments are frost-resistant bench marks designed to be anchored in permafrost (Figure 3-5).

e. Type E - Deep Rod - Frost Resistant (Anchored Below Permafrost). The primary difference between the Type E rod and the Type D rod is that the Type E will be anchored below permafrost as illustrated in Figure 3-6. Type E monuments shall be selected when the greatest monument stability is required in a permafrost area.

f. Type F - Shallow Rod - Finned, No Casing. The Type F shallow rod mark may be used in granular soils such as sands and gravels, glaciated soils or fine-grained soils such as silts and clays with high bearing strengths. The Type F rod mark is suitable for third order accuracy. If higher order accuracy is needed, then the Type A or Type B rod mark should be selected. The Type F rod mark is illustrated in Figure 3-7. Type F monuments shall also be used for reference and azimuth marks.

g. Type G - Disk in 3/4-inch Pipe or on Rebar. The Type G rod mark is selected for the same sites as the Type F mark; the primary difference is construction and installation details. The Type G rod mark is illustrated in Figure 3-8. Type G monuments shall be selected in lieu of Type F monuments when circumstances will allow the construction of the Type G monument.

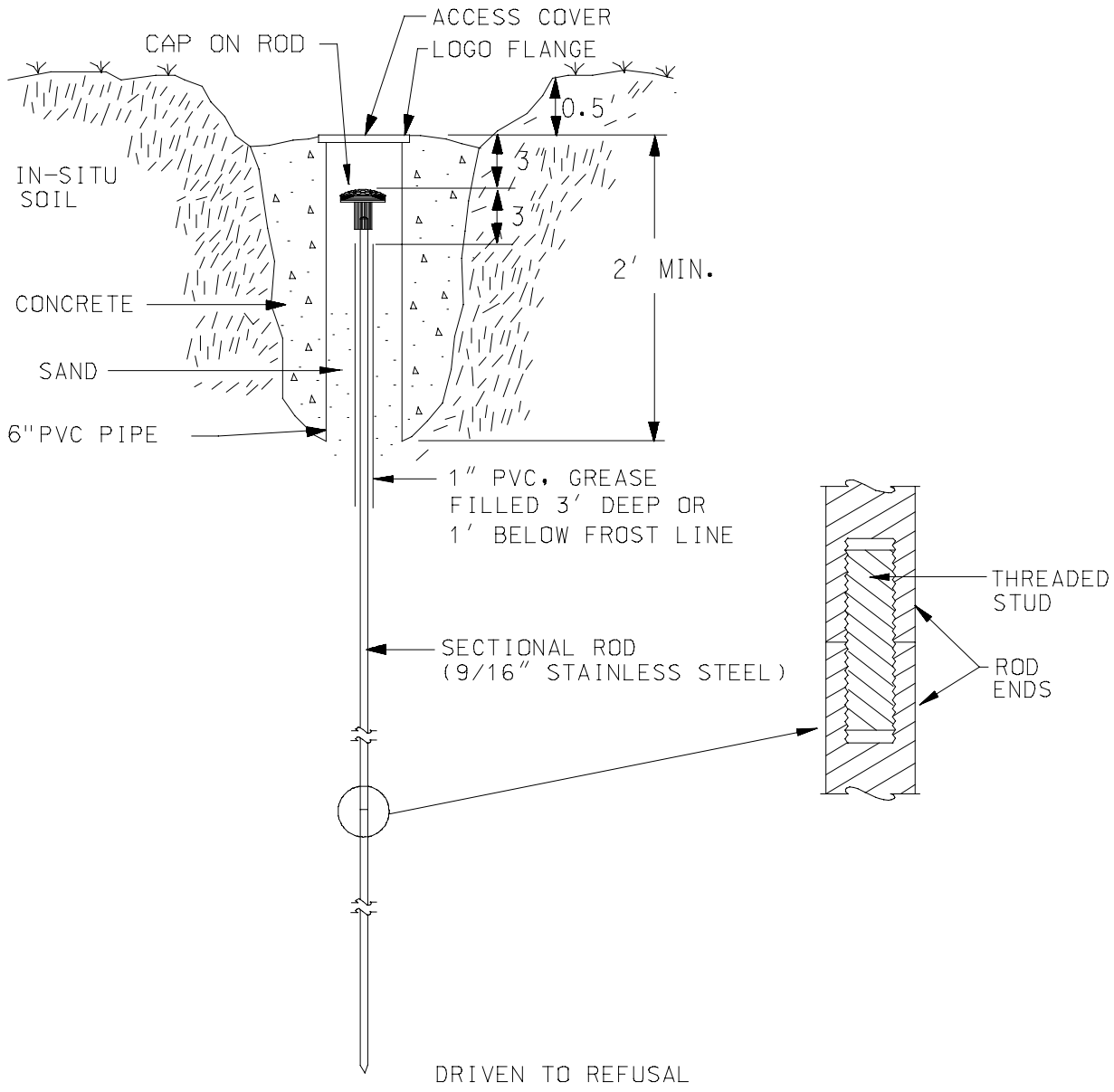
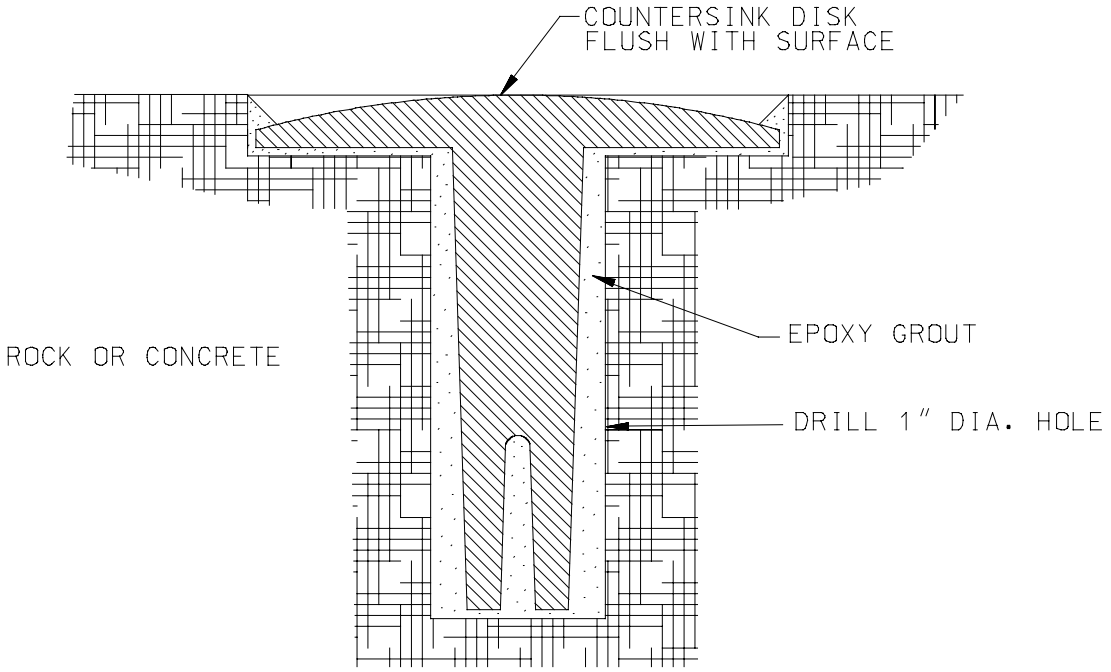


Figure 3-2. Type B monument - deep rod - stainless steel with sleeve



USE FOR VERTICAL, HORIZONTAL AND BOUNDARY CONTROL

Figure 3-3. Type C monument - disk in rock or precast concrete

h. Deep Bench Marks in Clay. When the site geology is known to consist of sensitive clays, the Type B rod mark should be used. The PVC sleeve should extend through the sensitive clay layer. The anchored section should be driven to refusal. When the site geology is known to consist of lacustrine clays, the Type B rod mark should be used. The PVC sleeve should extend through the highly desiccated soil.

i. Natural or Ready-Made Bench Marks. Occasionally, a natural or ready-made bench mark setting, which cannot accommodate a brass disk, will exist that would be more stable than a rod mark.

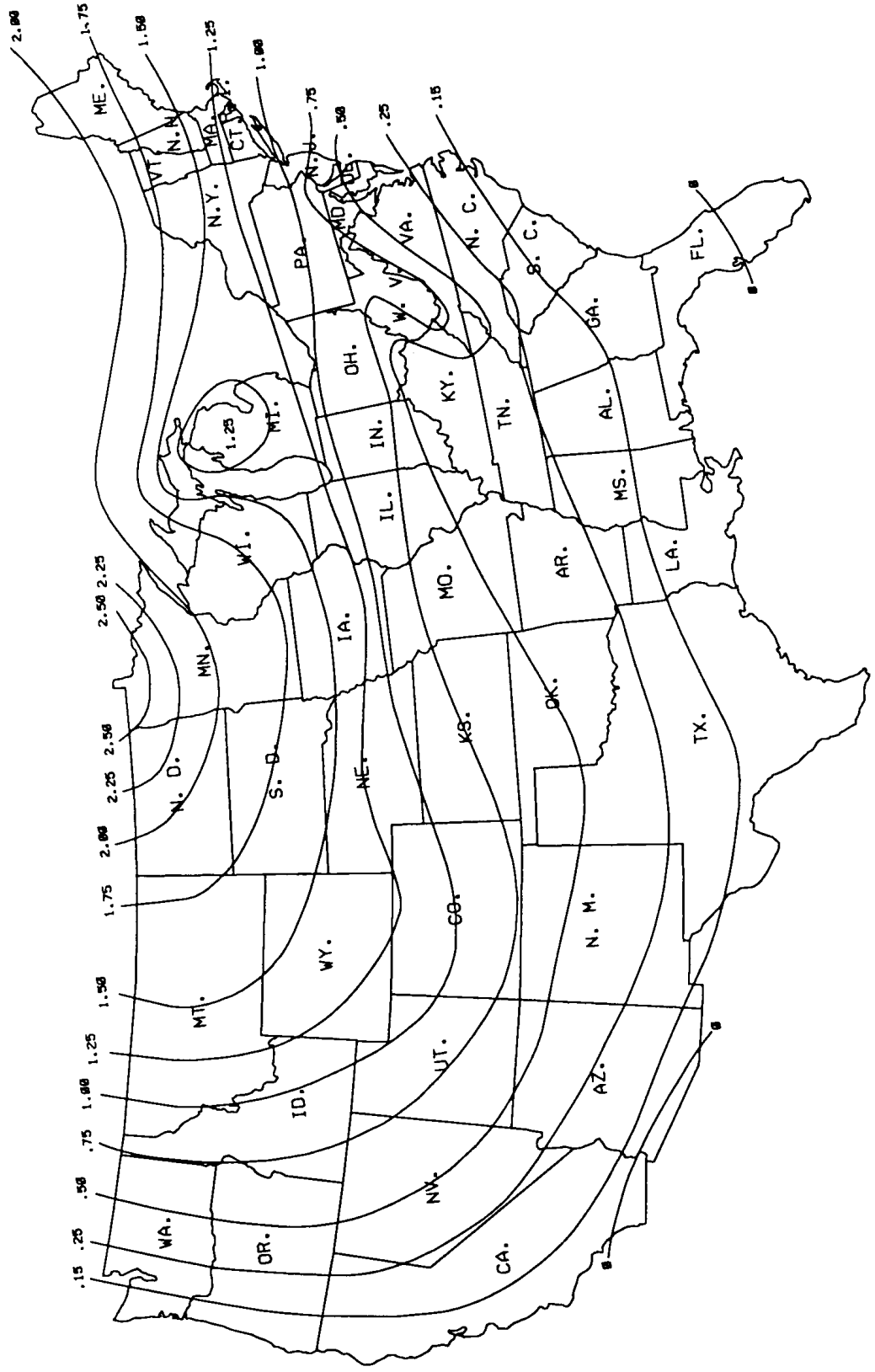
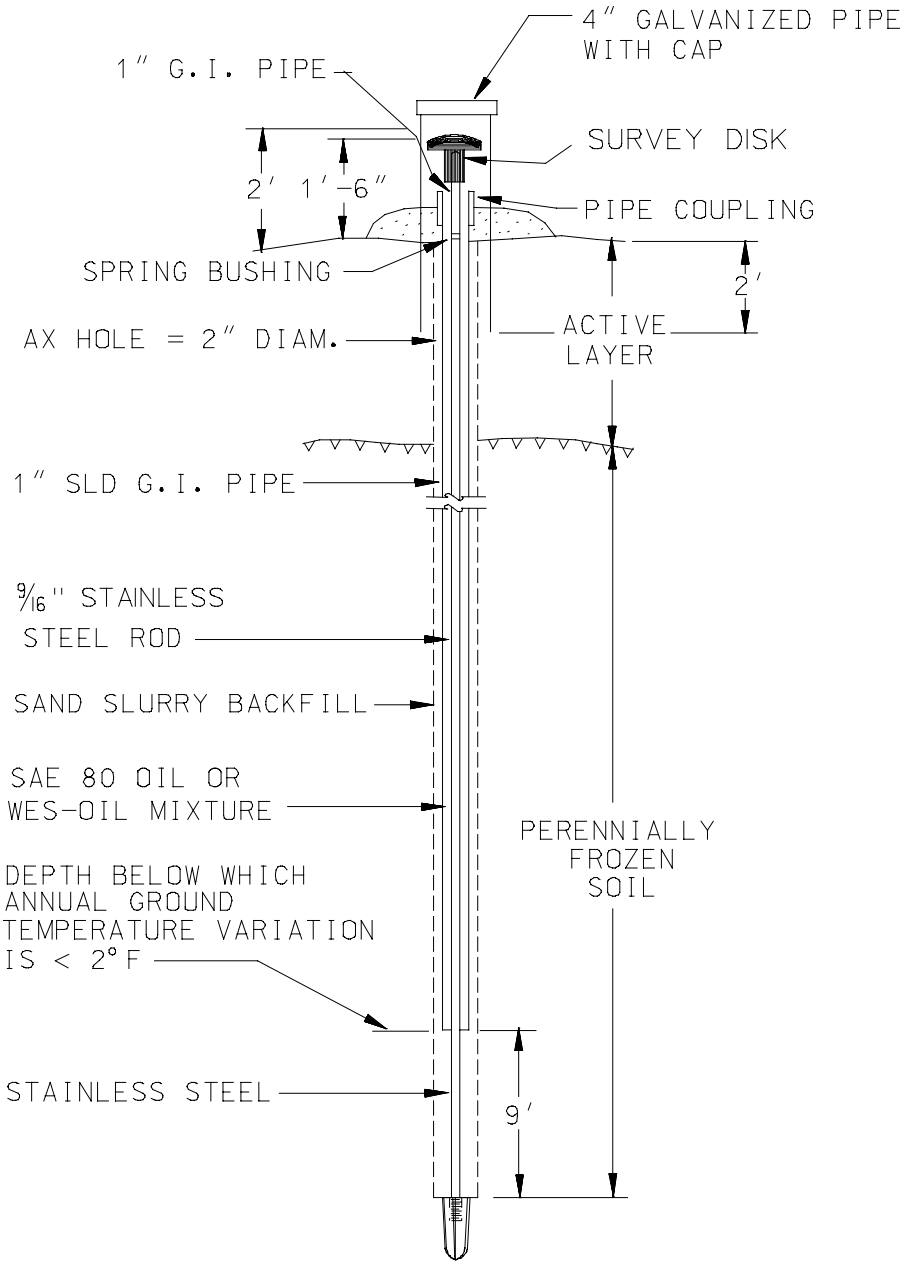


Figure 3-4. Maximum depth of frost (meters)



ANCHORAGE IN PERMAFROST

USE FOR VERTICAL AND HORIZONTAL CONTROL

Figure 3-5. Type D monument - deep rod - frost resistant in permafrost

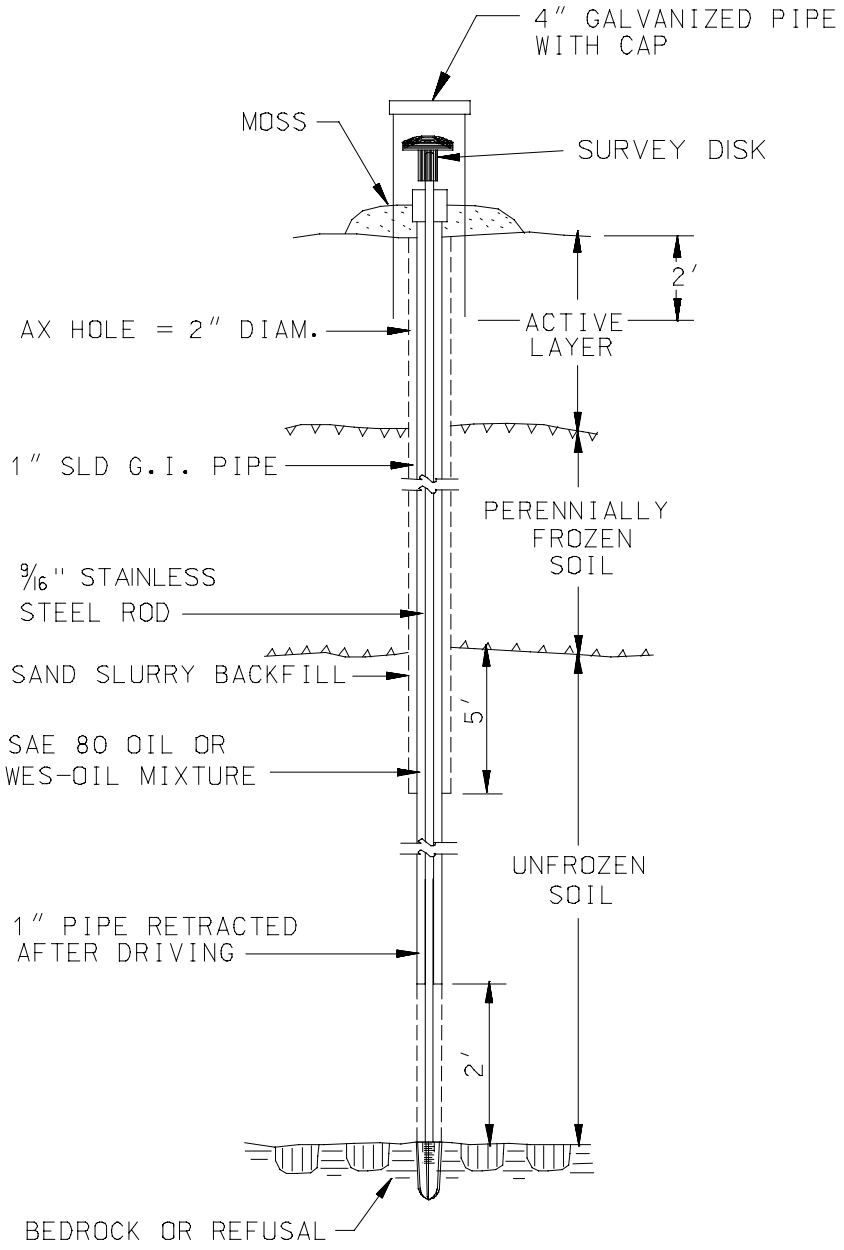
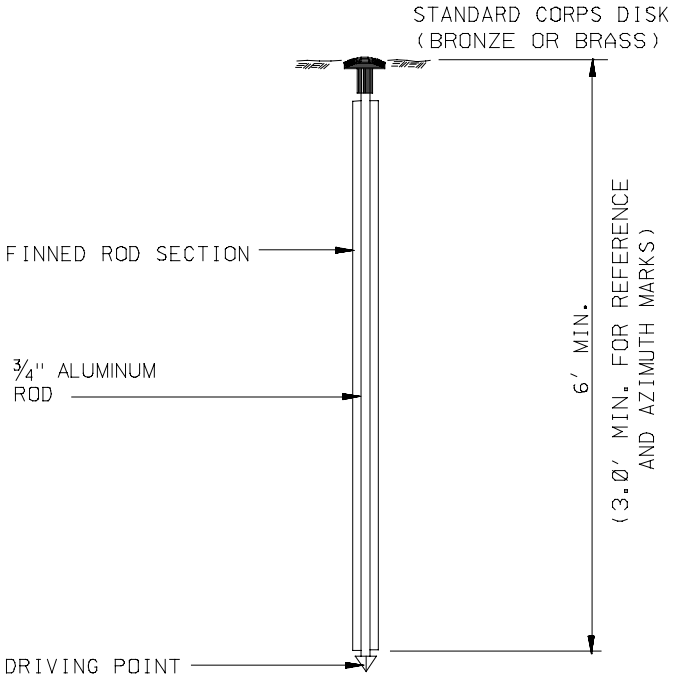


Figure 3-6. Type E monument - deep rod - frost resistant below permafrost



USE FOR HORIZONTAL, BOUNDARY, REFERENCE AND AZIMUTH CONTROL

Figure 3-7. Type F monument - disk on shallow rod

An example is a deep well casing. It would resist not only near-surface movements but also, to a degree, movements originating in the subsurface, such as subsidence from pumping. A good illustration of this can be seen in Santa Clara Valley, California, where well casings project prominently because of ground subsidence. These settings should not be ignored simply because a disk cannot be mounted on them. Settings of this type may furnish excellent references for elevations, provided they extend at least three times as deep as the required sleeve depth for a Type B rod mark in that area. It is important to select a good point of reference for the elevation of this type of bench mark. A prominent protrusion can be used if it is definite and has a good high point on which to rest a rod. Alternatively, a cross may be etched with deep, fine lines on a spot accessible to a leveling rod or tape. If possible, stamp or etch the bench mark designation and year nearby.

3-2. Construction and Installation Procedures. All USACE survey disks and access covers shall be stamped using 3.17-millimeter (1/8-inch) steel dies. All stamping shall deform the disk surface by a minimum of 1 millimeter (0.0394 inch).

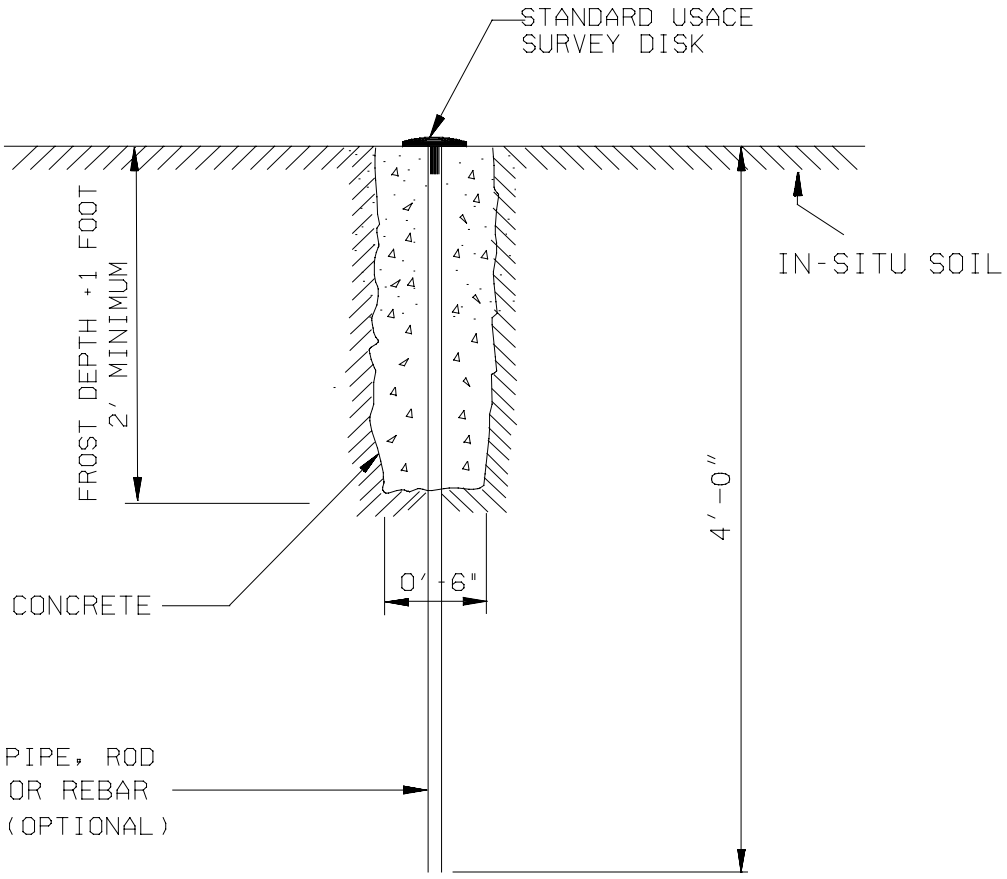


Figure 3-8. Type G monument - disk in cast-in-place concrete

a. Type A - Deep Rod - Aluminum with Finned Section. The construction details are shown in Figure 3-1. The mark is assembled from 3- and/or 4-foot sections of 3/4-inch aluminum alloy rod. The casement is constructed of a 15.2-centimeter (6-inch) PVC pipe 0.6 meter (24 inches) long, fitted with an aluminum access cover at the top. The access cover is imprinted with the information shown in Figure 3-9. The mark name shall be stamped on the access cover at "Mark Designation." The cover and pipe are placed around the top of the mark. Approximately 20 liters (2/3 cubic foot) of concrete is poured around the PVC pipe and access cover to hold them in place and to aid in recovery. The top 4-foot rod section is finned to provide horizontal stability. This type of monument is designed to prevent near-surface soil movements from disturbing the monuments. The rod assembly is driven or pressed to refusal into the soil so that it is anchored below the layers of disturbance. Refusal is defined as the depth at which the rod refuses to drive further or until a driving rate of 60 seconds or less per foot is achieved with a power reciprocating rod driver such as a Pionjar Model 120 or similar device

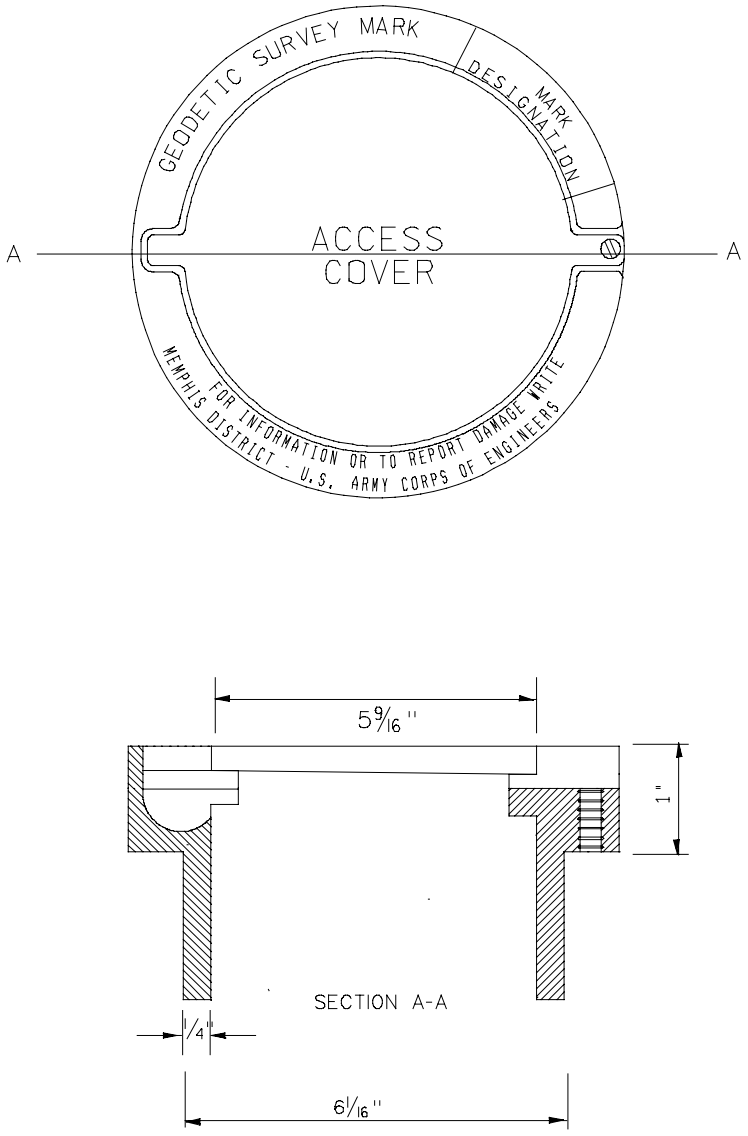


Figure 3-9. Standard access cover

with equivalent driving force of 26.9 foot-pounds/blow and an average of 2,500 blows per minute. The procedure for setting a Type A rod mark is as follows:

(1) Using an appropriate solvent for PVC, glue the aluminum flange to one end of a 0.6-meter (24-inch) section of 15.2-centimeter (6-inch) PVC pipe.

(2) Dig a hole 30 centimeters (12 inches) in diameter to a depth of 0.6 meter (2 feet).

(3) Drive the first section of rod in the center of the hole. Make sure it remains plumb while driving. Couple another section of rod tightly to the first and continue to drive the assembly. To obtain tight joints, hand tighten the sections and then apply another one-quarter turn with a wrench or wrenches. Repeat this procedure until the driving rate is near refusal. The last rod section shall be a 3-foot finned rod section driven such that its top is 3 inches below the surface.

(4) Stamp the name and year on the USACE disk (Figure 3-10) and drive the disk onto the rod. The disk should be driven on the rod about 1 inch.

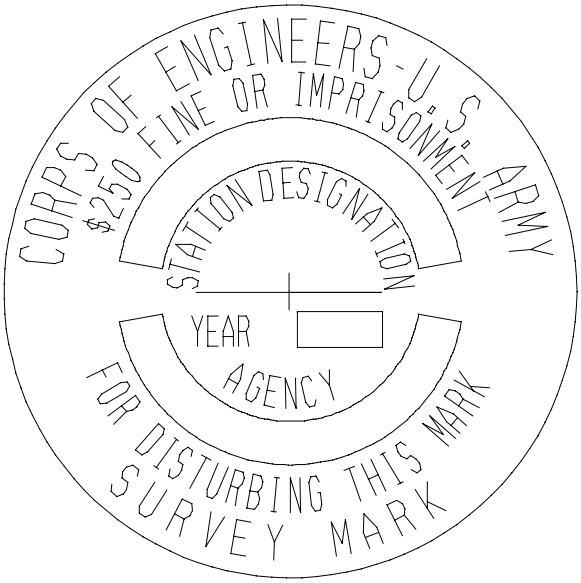


Figure 3-10. Standard survey disk

(5) Center the PVC pipe and access cover assembly over the rod. Backfill inside the pipe with sand to about 5 centimeters (2 inches) below the top of the rod.

(6) Mix about 20 liters (2/3 cubic foot) of concrete and place around the outside of the PVC pipe. Finish the top surface of the concrete so that it slopes slightly away from the top of the access cover.

b. Type B - Deep Rod - Stainless Steel with Sleeve. The construction details are shown in Figure 3-2. The rod is assembled from 3- and/or 4-foot sections of 1.43-centimeter (9/16-inch) Type 316 stainless steel coupled with threaded studs of the same material. The rod itself anchors the datum point to

a stable stratum of soil. For the most stable mark, the sleeve is required to isolate the rod from soil movements occurring above the stable stratum. The sleeve may be omitted if no soil movements are expected; however, stability will be reduced. To avoid movements caused by frost heave and soil shrinking and swelling, extend the sleeve to the maximum depth to where these types of soil movements are expected to occur. The procedure for setting a Type B rod mark is identical to that of the Type A rod mark with the exception of the sleeve and the finned section.

(1) Using an appropriate solvent cement for PVC, glue the aluminum flange to one end of a 0.6-meter (24-inch) section of 15.2-centimeter (6-inch) PVC pipe.

(2) Construct the sleeve by gluing a PVC cap, with a drill hole of adequate diameter to accommodate the rod, on each end of a 1-meter (3-foot) or longer section of 2.54-centimeter (1-inch) schedule 40 PVC pipe. Fill the sleeve with an insoluble, non-corrosive, cold weather type grease.

(3) Dig a hole 30 centimeters (12 inches) in diameter to a depth slightly greater than 1 meter (3 feet) or the depth required to place the sleeve pipe base 30 centimeters (1 foot) below the frost line.

(4) Taking care not to deform its end, by using a drive adapter, drive the first section of 1.43-centimeter (9/16-inch) stainless steel rod down to just above ground level. Make sure it remains plumb while driving. Couple another section of rod tightly to the first and continue to drive the assembly as noted in paragraph 3-2a.

(5) Insert the capped 1-meter (3-foot) or longer grease-filled section of 2.54-centimeter (1-inch) PVC pipe over the 1.43-centimeter (9/16-inch) rod. The PVC sleeve should extend at least 30 centimeters (1 foot) below the local frost line if the frost line is deeper than 90 centimeters (3 feet). The rod should protrude approximately 5 centimeters (2 inches) above the sleeve.

(6) Stamp the name and year on the survey mark disk (Figure 3-10) and drive the disk onto the rod.

(7) Backfill around the outside of the sleeve with sand to about 60 centimeters (24 inches) below ground. Install the 0.6-meter (24-inch) section of 15.2-centimeter (6-inch) PVC pipe with aluminum access cover over and around the sleeve and rod.

(8) Backfill the inside of the 15.2-centimeter (6-inch) PVC pipe with sand around the outside of the sleeve and rod to about 2.54 centimeters (1 inch) below the top of the sleeve.

(9) Pour concrete around the outside of the pipe and finish as outlined in paragraph 3-2a.

c. Type C - Disk in Bedrock or Concrete Structure. The Standard USACE disk (Figure 3-10) is made of brass or bronze. It is 8.9 centimeters (3.5 inches) in diameter with a spherical surface to support the foot of a leveling rod. Information is printed on this surface to identify the monument and to aid the user in obtaining important data. So as not to interfere with placement of the leveling rod, logo information is recessed in the surface of the disk. A deformed shank, about 7.5 centimeters (3 inches) long, is attached to the bottom surface of the disk to help prevent the disk from being dislodged from the monument. In addition, disks with tubular shanks are used when driven on rod marks. The step-by-step procedure for setting the disk in bedrock is as follows:

(1) Stamp the designation and year on the top surface using 3.17-millimeter (1/8-inch) steel dies.

(2) Pick a fairly level and accessible spot on the outcrop that is intact with the bulk of the rock.

(3) Drill a hole 2.5 centimeters (1 inch) in diameter about 10 centimeters (4 inches) deep into the bedrock. Recess the area around the top of the hole to a diameter slightly larger than that of the disk. When the installation is completed, the top surface of the disk should set level and flush with the surrounding rock. Caution: Safety goggles should be worn when drilling into bedrock or masonry.

(4) Remove any rock powder from the hole and recessed area. Fill the drilled hole with clean water and then pour in the epoxy or non-shrink grout. Mixing of the ingredients may be done in the hole. Premixed grout may be used if desired. By adding more water and grout, mix enough grout so that an extra amount is available for the underside of the disk and, if applicable, the inside of the shank. A properly mixed grout should be thick but still workable.

(5) Fill the depression on the underside of the disk with the additional grout. If the disk has a tubular shank, fill the shank with grout. This step is very important; it will prevent highly undesirable voids under the disk once it is in place.

(6) Place the shank of the disk into the drilled hole and press the mark firmly into place. Work the excess grout completely around the outer edge of the disk, making sure that it is smooth and flush with the top surface. An exposed edge of the disk would provide an area that could be used by someone to dislodge the disk. Excess fresh grout on the upper surface of the disk can easily be cleaned off.

(7) Sprinkle some dry cement on the exposed surface of the disk; then rub it with a clean rag using circular strokes. This will clean the disk very nicely, removing all excess grout from its surface and recessed letters. Rubbing the wet grout around

the edge of the disk in the same manner will do no harm. In fact, this is often done intentionally to finish its surface and prevent cracking. Brush away loose cement and make sure that the finished product has a very neat appearance.

(8) To prevent heavy rains from ruining its surface and/or to prevent the disk from being tampered with, the grout must be covered until it is set and dry. A piece of wood, cardboard, heavy paper, or any other similar biodegradable material will suffice.

(9) The installation is not complete until all accumulated trash has been picked up. Leave the monument location in a neat and orderly appearance.

When setting a disk in a massive concrete or masonry structure, first make sure the structure is stable. The required foundation depth is at least equal to a quarter of the specific sleeve depth of a Type B mark (Figure 3-2). The disk may be mounted vertically in a wall of a structure but should be set horizontally if possible. The procedure for setting a disk horizontally in a structure is identical to that for setting one in bedrock. Again, make sure safety goggles are worn when drilling into masonry or concrete. For a vertical setting, the hole for the disk's shank must be drilled horizontally; therefore, the mortar must be mixed separately. When drilling into brick or other soft material, a hammer and star drill should be used rather than heavy power equipment. This prevents the possibility of extensive damage to the exterior. The inside of the drilled hole should be wetted before any mortar is applied. After placing the shank of the disk into the mortar-filled hole, the disk should be worked to the bottom edge of the hole. This will prevent the possibility that the disk will settle askew while the mortar is curing.

d. Type D - Deep Rod - Frost Resistant (Anchored in Permafrost). Construction of this type of monument should be accomplished when the ground is frozen. Plywood should be used in the work area to minimize surface disturbances that destroy the organic mat around the bench mark leading to deepening of the active frost layer and possible instability of the monument. The installation of this bench mark design is outlined below.

(1) Carefully position the drill rig so that disturbance of the moss cover will be kept to a minimum. Place a suitable length of NX (4-inch) casing through the active layer into the perennially frozen ground to prevent thawed material and surface water from entering the hole. Drill a hole to a depth of 39 feet with AX (2-inch) size drill equipment, using an AX core barrel if samples are desired; otherwise, use an AX non-coring bit. If caving occurs, AX drill casing should be placed to the bottom of the hole. When the hole is completed, bail out all the water.

(2) Connect the drive point to a section of 9/16-inch stainless steel or aluminum rod and lower it into the hole to a depth of 8 feet. String a 10-foot length of 1-inch pipe over an 11-foot length of the rod. With vice grips or another device securely clamped to the top of the inner pipe to prevent it from sliding out of the 1-inch casing, raise the two pipes vertically above the hole and connect the rods. Retaining a hold on the outside pipe, lower the assembly into the hole, adding successive sections of rod and 1-inch pipe until the drive point rests on the bottom. Secure the 1-inch pipe so that it projects about 6 inches above the ground. The inner pipe should protrude above the outer pipe.

(3) Holding the pipes in this position, carefully backfill the hole with a sand-slurry mix so that it just pours easily. If drill casing has been used, withdraw it carefully so that the relative positions of the bench mark rod and pipe are maintained as the hole caves in around them. To ensure that the lower portion of the datum pipe is adequately surrounded by soil, it may be necessary to fill the lower part of the hole with the slurry before removing the drill casing. If this is the case, even greater care is required to maintain the relative positions of the bench mark rod and pipe as the drill casing is removed.

(4) Remove the NX casing from the active layer and backfill the hole to the ground surface, carefully replacing the moss cover around the pipes.

(5) Fill the annular space between the inner and outer pipes with an SAE 80 gear oil or a special wax-oil mixture. This mixture can be made up of 70 percent oil (such as Mentor 29) and 30 percent wax (such as Socony Mobil Cerise AA) by weight, mixed after heating to about 200^{o}F. The mixture is poured into the assembled sections of pipe and allowed to congeal before the pipes are placed in the drill hole.

(6) Install the "spring bushing" inside the top of the 1-inch pipe casing. The top of the rod shall be rounded to provide a single point of contact. Center punch the datum point for a three-dimensional monument.

(7) A 4-foot length of 4-inch pipe with pipe cap shall be driven into the ground over the bench mark assembly to provide protection.

e. Type E - Deep Rod - Frost Resistant (Anchored Below Permafrost). Construction of this type of monument should be accomplished when the ground is frozen. Plywood should be used in the work area to minimize surface disturbances that destroy the organic mat around the bench mark leading to deepening of the active frost layer and possible instability of the monument. The installation of this bench mark design is outlined below.

(1) Following the same procedures given above, drill an AX hole to a depth 5 feet below the perennially frozen layer.

(2) If the unfrozen soil underlying the permafrost is relatively soft, complete the installation by driving the 2.54-centimeter (1-inch) pipe and the rod to refusal; then retracting the 2.54-centimeter (1-inch) pipe 0.6 meter (2 feet) above the refusal point.

(3) If the unfrozen soil is stony or very stiff, it may be necessary to extend the borehole to bedrock or other resistant material. In this case, the installation may then be completed by following the procedures used for anchoring bench marks in permafrost previously discussed.

f. Type F - Shallow Rod - Finned, No Casing. The construction details are illustrated in Figure 3-7. The Type F mark is constructed of two 90-centimeter (3-foot) aluminum alloy finned rod sections with a USACE disk driven on the top section. The rods are driven or pressed into the soil such that the USACE disk is flush with the ground surface.

g. Type G - Disk in 3/4-inch Pipe or on Rebar. The construction details are illustrated in Figure 3-8. The Type G mark is constructed by excavating a 15-centimeter (6-inch)-diameter by 60-centimeter (2-foot)-deep hole. In areas where the maximum frost depth is greater than 2 feet, the excavated depth should be 1 foot below the maximum frost depth. The USACE disk may be driven into a 4-foot by 3/4-inch diameter pipe or on a 4-foot by No. 5 reinforcement steel bar (rebar). The pipe or bar assembly is then driven into the center of the hole until the disk is slightly above the surface. The hole is then filled with concrete to the disk. The use of a pipe or rebar is optional. The disk may be pushed directly into the fresh concrete; however, a magnet shall be placed in the concrete if pipe or rebar is omitted.

3-3. Naming Vertical Control Monuments. A vertical control point, commonly referred to as a "bench mark" (BM), should be identified by a number or by an alphanumeric symbol stamped on the respective disk marker (or otherwise inscribed on the bench mark monument or access cover). In principle, the name that identifies a vertical control point for publication purposes should be the same as the name that actually appears on the marker. However, extraneous information, which is not part of the name, frequently appears on the marker. For example, the name of a bench mark should not include the elevation. The name does not generally include the "year mark set". Tidal and water level stations should also be named in accordance with these instructions.

a. Maximum Character Length. A bench mark name must not exceed 25 alphanumeric characters (including all imbedded

blanks). Abbreviate and/or edit a name as necessary to conform to this limit.

b. Organization Acronym. A name should always include the acronym or abbreviation of the agency or organization that set the mark if it is not precast or stamped on the survey marker (for example, USE for U.S. Engineers). In addition, a District or Division acronym may also be included as part of the name if it is not precast or stamped in the marker. The agency and/or organization acronym should not be stamped on the disk as part of the name. However, they may be appended to the name for publication.

Example Names

2903
V 16 RIRR

c. Special Characters. The only special characters permitted in a bench mark name are the blank ( ), plus (+), minus or hyphen (-), equals (=), slash (/), and decimal point (.). When used, these special characters must not be separated from adjacent characters by any blanks. Commas and parentheses are not allowed to appear in a bench mark name.

Example Names

CH 1174=297+00 A
H 23

d. Character Groupings. All alpha and numeric character groupings in a name must be separated by a blank. Care should be taken that only one blank is used for this purpose. Two blanks in a row will be interpreted as the end of the name.

Example Names

MEM 123 B
BEALE 17 B
TT 1 7 B

e. Unacceptable Names. The characters "NO" or "NO." should not be included in the name when used as the abbreviation for the word number. A period may not appear imbedded in or adjacent to a grouping of alpha characters. However, a decimal point may appear imbedded in, or adjacent to, a grouping of numeric characters. Non-specific descriptive terms such as "bench mark," "BM," "chiseled square," "bolt," "red," "nail," or "spike" should

not be used as part of the name. The elevation should not be stamped on the disk marker or otherwise inscribed on the bench mark monument.

Acceptable Example Names

MI 14.2
4419.
PALMER NE BASE

f. Multiple Names. For bench marks that carry multiple stamped names, the information imprinted should be concatenated with the equal sign (=) used as a separator (subject to the 25-character total length limit).

Example Names

H 13=872 2621 TIDAL USE
STA 3=MI 182.5 USE
LEE RM 1=R 13 USE

g. Reset Names. When resetting marks, always use a new unique name for each station reset. Do not use "Reset" as part of the name.

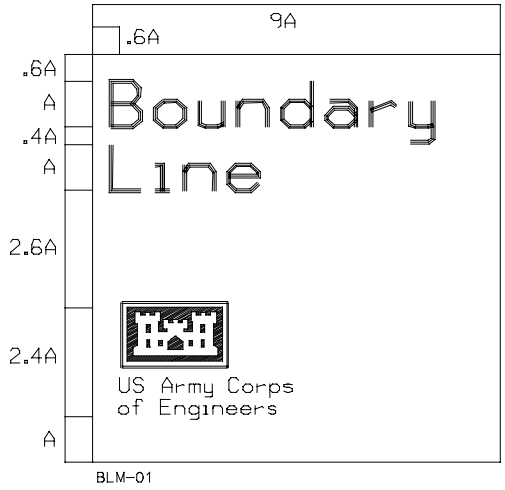
h. Temporary Bench Marks. A temporary bench mark (TBM) must carry the letters "TBM" as the first three characters of the name.

Example Names

TBM 1 A
TBM 14

3-4. Marks of Other Organizations. If a satisfactory vertical control monument of another organization is found at the project site in good condition, it may be used without alteration as the station mark of a new USACE Survey Monument. In case the existing mark of the other organization is not in good condition for a station mark, a new station mark should be established in the vicinity, and the mark of the other organization should be used as an extra reference mark. The stamping of additional marks should be done as indicated in this manual. Care should be taken not to displace a mark of another organization in horizontal position, or even in vertical position if there is a possibility that it could be used as a bench mark. The mark should not be altered without permission from the organization that established it.

3-5. Witness Posts and Signs. In order to aid in the preservation and to serve as a means of easy recovery of monuments being established, a witness post should be set adjacent to the monument or near one of the reference marks at each station. This post should be 1.8 meters (6 feet) in length and be set to a minimum of 1 meter (3 feet) above the ground surface. The post should have the standard witness post sign attached (Figure 3-11). Witness posts shall be set for monuments of third-order accuracy and above, established along public highways, in rural districts, along the rights-of-way of railroads, and along the shorelines of rivers and lakes. They need not be set for monuments established along business streets, in residential sections of cities, on the grounds of a school or a church, in cemeteries, in cultivated farmlands, or on bare mountain tops. For survey monuments established below grade or in cultivated fields and marked with an underground mark, the post shall be set at a reference mark.



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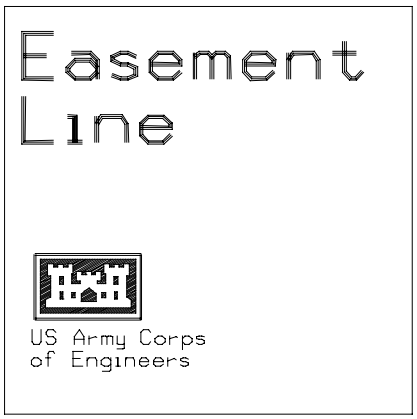
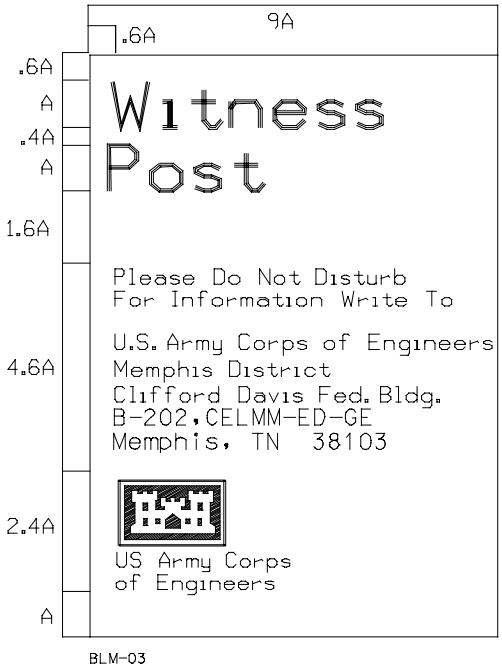


BLM-02



BLM-03

SIGN TYPE	LEGEND SIZE (A)	PANEL SIZE	POST SIZE	SPECIFICATION CODE	MOUNTING HEIGHT	COLOR BKG/LGD
BLM-01	.3437	3.5"x3.5"	4"x4"	SCP-7	36" MIN.	WH/BK
BLM-02	.6875	6"x6"	4"x4"	SCP-7	36" MIN.	WH/BK
BLM-03	.3125	2.875"x2.875"	3.75"x.5"	SCP-10	36" MIN.	WH/BK

Figure 3-11. Standard property markers